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INJECTING METASYSTOX-R[1] INCREASES SEED YIELDS OF LARGE SUPERIOR DOUGLAS-FIRS BY REDUCING LOSSES CAUSED BY CONE INSECTS

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ABSTRACT

A pilot project was conducted in northern California to evaluate the feasibility and biological and cost effectiveness of injecting large Douglas-firs as a means of increasing seed yields. Results demonstrated that injection with Metasystox-R will protect seed crops against the Douglas-fir cone moth and cone gall midge. Effectiveness against the Douglas-fir seed chalcid was not expressed. Results were used to construct cost effectiveness curves based on the value of seeds protected and the size of cone crop per tree.

1. Mention of commercial products does not constitute endorsement by the U.S. Department of Agriculture to the exclusion of other products that may be suitable. See precautionary statements on last page.

INTRODUCTION

Need for Seeds. Federal, state and private nurseries in California used about 3400 pounds of Douglas-fir, Pseudotsuga menziesii (Mirb) Franco, seeds in 1978. This amount is expected to increase to at least 4000 pounds annually under the impetus of the California Forest Practices Act and the National Forest Management Act of 1976 that prescribes greater reforestation efforts (Koerber 1979). Reforestation with improved Douglas-fir stock on National Forest lands is to increase from the present 11,000 to 12,000 acres per year to about 17,000 to 18,000 acres in the mid-1980's. If these mandated goals are to be met and there is to be sufficient additional seeds to reforest burns, then losses of Douglas-fir seeds caused by cone and seed insects must be reduced to ensure that such quantities are available.

The tree improvement plan for National Forests in the Pacific Southwest Region calls for a base-level program of seed collection from better-than-average trees in several well-distributed stands within each seed zone, and it details a high-level program of improvement through clonal seed orchards of selected trees with associated progeny tests (Kitzmiller 1976). All Douglas-fir seeds now sown in Forest Service nurseries meet the base-level guidelines. Four thousand pounds of seeds collected at each program level would be worth $360,000 and well in excess of $1,000,000, respectively.

Insects annually destroy from 26 to 98% of the Douglas-fir seed crop in California (Koerber 1960, 1979). When the majority of the seed crop is destroyed by insects, harvesting and processing of cones become inexpedient and tree improvement impossible. Low reserves or depleted seed stocks are often the result, and this can lead to the use of poor quality seeds and of improper seed source in reforestation. Loss of seeds from superior trees is intolerable because of the gains in growth and form that the seeds could produce.

The Insects. Most of the seed losses in the Douglas-fir of the Klamath Mountains of northern California are caused by four insects. Along the coastal slopes the Douglas-fir cone gall midge, Contarinia oregonensis Foote (Diptera: Cecidomyiidae), causes high levels of damage. In more inland areas the Douglas-fir cone moth, Barbara colfaxiana (Kearfott) (Lepidoptera: Olethreutidae), and the Douglas-fir seed chalcid, Megastigmus spermotrophus Wachtl (Hymenoptera: Torymidae), occur with increased frequency. The fir coneworm, Dioryctria abietivorella (Grote) (Lepidoptera: Pyralidae), can also damage large quantities of cones and seeds in some years.

Injection. In general, biological controls tend to be inadequately effective against seed pests (Way and Bevan 1977). Therefore, an effective and economical chemical method is required to ensure that insects do not interfere with the production of necessary quantities of Douglas-fir seeds. The feasibility of using sprays is limited because spring rains in the Douglas-fir region limit the effectiveness of foliar aerial sprays, aerial sprays are politically sensitive in northern California, ground application of sprays is not practical for tall trees, and chemical controls once available for insect pests are no longer in use. Injection of Metasystox-R (oxydemetonmethyl) was chosen because research results have indicated that

injection will reduce the number of seeds destroyed by cone moths and gall midges (Schenk et al. 1967, Koerber 1979). Futhermore, the method has the following additional advantages:

1. Premixed. Metasystox-R® comes wholly contained in preloaded disposable injector units (Inject-A-Cide®, J.J. Mauget Co., Burbank, CA[1]) containing 3 ml of the 50% technical insecticide. No mixing is required and this greatly facilitates efficiency and worker safety.

2. Minimal exposure of the environment. Application is made within host tissue, not broadcast in the environment. There is no external residue as a source of contamination, and the material breaks down rapidly.

3. Minimal exposure to the applicator. Because the insecticide is premixed and packaged, the applicator needs only rubber gloves and, in the unlikely event of an inadvertent puncture of a pressurized unit, protective clothing such as coveralls and a facial visor.

4. Simple transportation. Movement of bulky material, packages and equipment is not necessary. Units, tools and protective gear required to treat 90 trees can be contained easily in the trunk of an auto.

5. Easy storage and disposal. Little space and no additional facilities are required to store the units for the short time between delivery from the supplier and application. Used units can be easily packaged for movement to proper disposal sites because of their small size. No material will be released at the disposal site because the insecticide degrades years before the plastic applicator unit loses its integrity.

6. Only simple training needed. The method of application is simple and straightforward, and can be illustrated and taught in 15 minutes.

The Douglas-fir injected during research projects were only 9-15 inches in diameter (dbh), and the Pacific Southwest Region Tree Improvement Program is in need of cost-effective production of seeds from the large (ave. dbh 23"), superior Douglas-firs that form the base of the Tree Improvement Program. Therefore, this pilot project was undertaken to evaluate the feasibility and biological and cost effectiveness of injecting large Douglas-firs as a means of increasing seed yields.

METHODS

One hundred and twenty superior Douglas-fir trees located on the Klamath National Forest in northern California were divided into 60 pairs that had the members of each pair in close proximity to each other and occupying similar habitats. One tree of each pair was to serve as a control while the second was to be treated. Unfortunately, a severe late frost damaged the cone crop on many of the trees selected, resulting in 27 superior treated trees paired with 5 superior and 22 nonsuperior controls. Geographic, habitat and size similarities within each pair were maintained. The treated trees averaged 23.2 inches (16-30") in dbh, 129 feet (89-169') in height, and 74 years (54-116 yrs) of age.

Most of the treated trees were injected at breast height with the systemic insecticide Metasystox-R by use of Inject-A-Cide units at the registered rate of 3 gm of 50% technical material per 6 inches of tree circumference at dbh. Those few trees located within easy visibility of roads, trails and other areas frequented by forest users were injected not at dbh, but at approximately 10 feet above ground level in order to reduce the probability that units would be disturbed while on the trees. All treated trees were tagged with a standard-size, green and white Forest Service sign that gave notice of the treatment, why the treatment was done, date of treatment, and who to contact in case of questions or comments. All procedures were subject to review in an environmental assessment prior to the treatments.

Application of each injection unit always follows a standard procedure. With a special tool, the applicator drives a thin, nail-like aluminum tube into the actively translocating outer portion of the sapwood until the tube is firmly set. A unit containing the 3 grams of insecticide is then pressurized by squeezing together the top and bottom halves of the capsule. The applicator taps the inverted unit onto the tube until the tube punctures a diaphragm designed into the unit, and then turns the unit upright. The pressure forces the insecticide through the tube into contact with the water-conducting system of the tree for absorption and translocation into the crown. The more active the transpiration and translocation of water, the more rapidly the systemic is absorbed. Thus, warm clear days favor rapid uptake moreso than cool, overcast days.

The units are turned downward before removal to drain resin and residues away from the punctured diaphragm. Once removed they are placed in a heavy plastic bag along with the aluminum tubes that must be removed from the trees with pliers.

Injections took place between April 23, 1980, and May 14, 1980. At the time of injection, female flowers (strobili) on the trees were: 1) erect-open (7 trees), 2) erect-closing (2 trees), 3) closed and turning downward (6 trees), and 4) pendant-closed (12 trees). The recommended stage of flower development for treatment is erect and open. Units were left on the trees from 2 to 44 days and were removed in the course of other field assignments, because of travel restrictions and the widely scattered distribution of the pairs.

Upon cone maturity in September, but before dehiscence, as many cones as possible were collected from each tree, and a subsample of 20 cones was taken randomly from each of these collections. Two trees used in the analysis bore only 14 cones each because of the early frost damage. Cones of the subsample were dissected scale by scale and damage was recorded by causal insect. All or a random sample of 248 extracted seeds per collection were x-rayed to determine the proportion of seeds that were filled, hollow, defective, or infested by the seed chalcid. Final seed counts were adjusted proportionately to the x-ray data and for the proportion of seed destroyed by the cone moth that was likely to be aborted or infested by the cone gall midge and the seed chalcid. Without this adjustment, the importance of these two insects would be underestimated and could lead to optimistic seed forecasts based on control of only the cone moth. Other

insects for which examinations were made were the coneworm, Dioryctria abietivorella, and the resin midge, Asynapta hopkinsi Felt (Diptera: Cecidomyiidae).

RESULTS AND DISCUSSION

Injection significantly increased the number of sound seeds per cone from an average of 6.8 to 17.8, an increase of 160% (Table 1). This increase was largely the result of the significant decreases in damage caused by the Douglas-fir cone moth and the Douglas-fir cone gall midge. Control of the cone gall midge was probably greater than is indicated in Table 1 because on one tree, 5 of 11 units failed to empty completely and only on this tree did the cone gall midge cause heavy damage (39.8% seed loss).

Injection of trees at different stages of flower development did not have any significant effect on the level of control achieved. However, a trend was found within the chalcid damage despite the variability of the data. Seed loss per tree to the seed chalcid was 2 to 3 times greater when the injection took place when the flowers were open (12.4%) than when they were pendant (3.4%). Previously, the accepted time for injection was when the flowers were erect and open. However, it is difficult to treat a large number of widely scattered trees with different rates of flower development when flowers are erect and open. Delaying injection until flowers are pendant, which would make timing less critical, apparently does not reduce suppression of the gall midge and cone moth and may result in reduced losses from seed chalcid.

Table 1. Damaged, sound and infertile seeds extracted from cones of Douglas-fir trees untreated and injected with Metasystox-R

			Seed Damaged By					
	Filled	Infer-tile	Cone Moth	Gall Midge	Chalcid	Resin Midge	Cone-Worm	Total
Control								
No. Seeds per Cone	6.8	27.0	11.8	3.2	3.7	0.2	0.2	53.2
Percent	12.9	50.8	22.2	6.3	7.0	0.3	0.3	
Injected								
No. Seeds per Cone	17.8*	28.7	0.3*	1.4**	3.4	0.4	0.0	52.1
Percent	34.2	55.1	0.5	2.6	6.5	0.8	0.0	

*, ** Injected significantly different from control at P = 0.01 and 0.05, respectively.

Hollow and defective seeds as determined from the x-rays were 29.4% for the injected trees and 38.5% for the controls. This relationship is the reverse of the 55.1% and 50.8% for the total infertile percentages (Table 1). Therefore, it appears that the injected superior trees had a greater level of aborted rudimentary seeds than the primarily nonsuperior controls. Whether this is a regular occurrence or an aberration is unknown, but it is probably the result of poorer pollination in superior Douglas-fir, and not a result of the treatment.

Only one unforeseen event took place during the injection period - the first known contact between injecting units and wildlife. Units on 4 of the 52 injected trees were disturbed by bears. All units apparently were empty at the time of disturbance, for only a film of residue was found in the dislodged units. The units apparently were unpalatable because all were left near the tree, even those bearing tooth punctures. Prompt removal after uptake would lessen the probability of wildlife contact and could be done by any field crew equipped with a pair of pliers for tube removal, a heavy plastic trash bag for disposal, and protective rubber gloves.

Does Injection Pay? This question relies basically on another, "How much are the seeds worth to those in charge of reforestation?" Many of the costs involved in the project, such as tree selection and cone collection, are encountered in every cone collection effort. Therefore, the additional costs of injection are the salary, travel and materials involved in the application and timing of injection. These expenses amounted to $1,846.60 in this project, or $68.39 per injected tree (Table 2). If this is considered a basic operational cost per tree, then one can calculate the number of cones that must occur on a tree before injection will produce a yield of seeds valued at the cost of injection. Any number of relationships could be constructed from the data, but only four are given (Fig. 1).

Given 32,546 seeds per pound (USDA-Forest Service 1974) and given that 43.7% of the developed seeds thought to be sound were found to be hollow, defective or infested with the seed chalcid when x-rayed, 57,808 seeds would have to be collected to yield a pound of seeds at 100% Pure Live Seed (PLS). Using the present yield of 18 filled seeds per cone after extraction and separation (Table 1), many cones must be present for injection to be cost effective (Fig. 1, Curve A). Assuming 32,546 seeds per pound without any correction factor, or that 35,000 seeds per pound at 93% PLS (a frequent California standard) can be achieved, then a smaller number of cones must be present for cost effectiveness (Fig 1, Curve B). The number of seeds per cone was found to vary from 26 to 50 in an early survey (Willis 1917) and averaged 68 in a pollination study (Ho 1980). A yield of 27 filled seeds per cone is well within reason with proper pollination. Koerber (1979) had several collections with more than 27 sound seed per cone. This yield greatly reduces the number of cones that have to be protected to cover costs (Fig. 1, Curve C).

In a seed orchard, seed production area, or selected grove of large trees within a seed zone, the costs of injection would be approximately halved because travel and salary costs would be greatly reduced. Twenty-seven trees is about the number of trees that a crew of two could treat in an 8-hour day, and $25.00 per tree appears to be a minimum, basic cost under

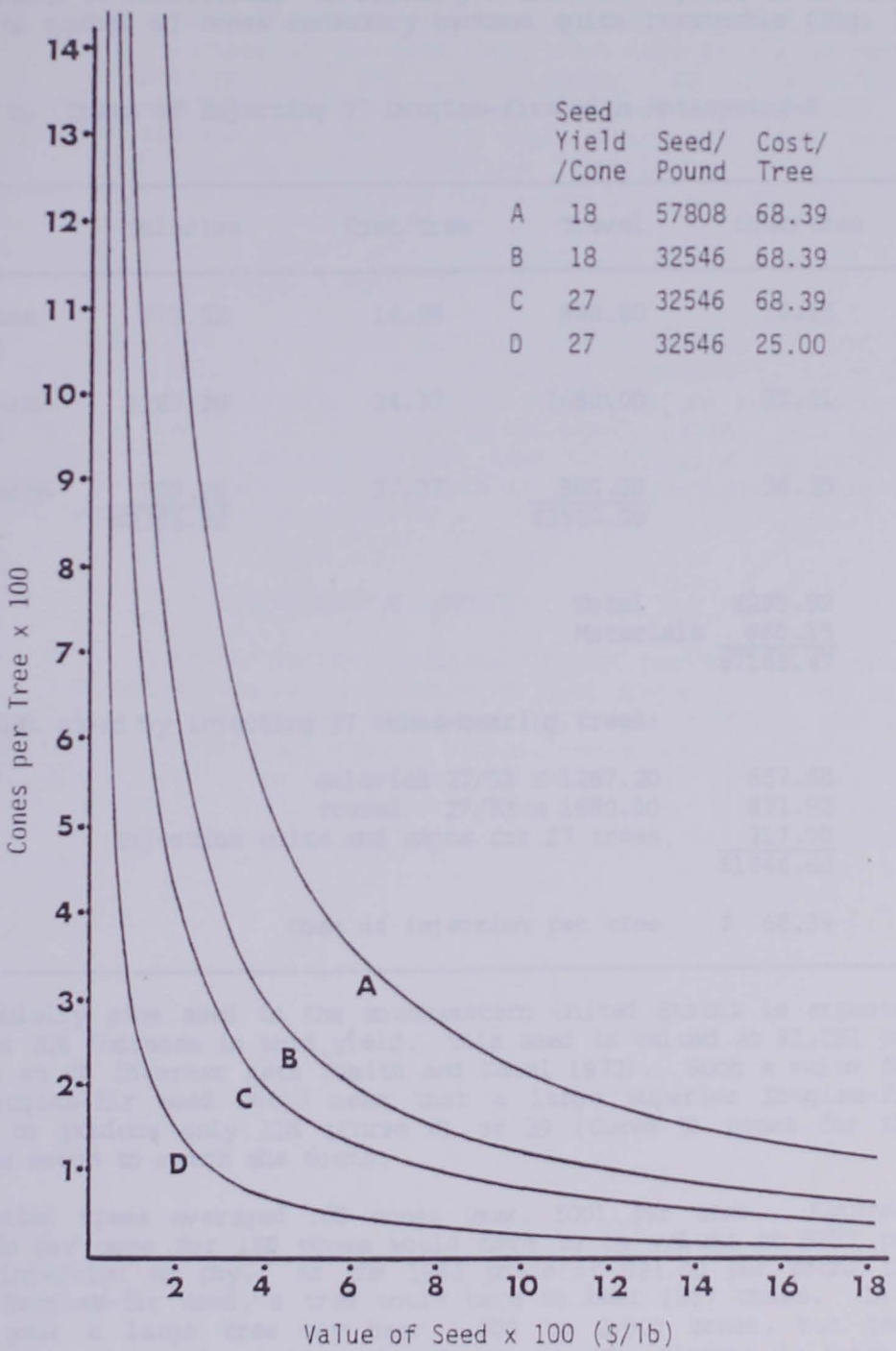

Figure 1. The number of cones per tree needed before injection of Metasystox-R is cost effective at a fixed value per pound of seed.

the most optimum of conditions. At $25.00 per tree and a yield of 27 seeds per cone, the number of cones necessary becomes quite reasonable (Fig. 1, Curve D).

Table 2. Costs of injecting 27 Douglas-firs with Metasystox-R

Activity	Salaries	Cost/Tree	Travel	Cost/Tree
Tree Selection (52 pairs)	779.52	14.99	840.00	16.15
Tree Injection (52 trees)	1267.20	24.37	1680.00	32.31
Cone Collection	739.20	27.37	980.00	36.30
	$2785.92		$3500.00	

Total	6285.92
Materials	880.55
	$7165.47

Cost added by injecting 27 cones-bearing trees:

Salaries 27/52 x 1267.20	657.68
Travel 27/52 x 1680.00	871.92
Injection units and signs for 27 trees	317.00
	$1846.60
Cost of injection per tree	$ 68.39

Improved loblolly pine seed in the southeastern United States is expected to produce a 20% increase in wood yield. This seed is valued at $1,051 per pound using an 8% interest rate (Smith and Zobel 1972). Such a value for improved Douglas-fir seed would mean that a large superior Douglas-fir would have to produce only 118 (Curve C) or 39 (Curve D) cones for the value of the seeds to match the costs.

The 27 treated trees averaged 160 cones (max. 500) per tree. Eighteen filled seeds per cone for 160 cones would have to be valued at $772 per pound for injection to pay. At the 1980 price of $91.00 per pound for California Douglas-fir seed, a tree would have to bear 1357 cones. In a good seed year a large tree may bear 1,000 to 2,000 cones, but good Douglas-fir cone crops are cyclic and infrequent. The picture is further complicated by the cone collection procedures instituted in California for achieving a base level improvement in planting stock.

Cone collection guidelines call for a minimum of 20 stands to be represented for bulked collections from each seed zone. If 80 pounds of seeds are needed for a 10-year backlog in the seed bank, then each of the 20 stands would need 4 trees each producing one pound of seeds. The number of trees needed per stand would vary with the number of stands per zone and the quantity of seeds needed, but the number would almost always be small. This should increase the chances of limiting injection to trees with a large number of cones, and thus increase the probability of cost effectiveness. However, it also drives up the costs in terms of salary and travel because the stands must be separated by at least 200 yards, and the distance is often several miles in rugged terrain.

The trees in this project were located within 4 seed zones and the cost per tree for injection within one seed zone should be considerably less than $68.39, but it would not approach the optimum of $25.00 per tree estimated for large trees in seed production areas or selected groves. The forest officer in charge of cone collection will have to determine the worth of seeds that can produce increased wood yields and site-correct planting stock, and the benefits of tree injection.

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Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides where there is danger of drift when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment, if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

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